

A Bench-scale Centrifuge Dewatering Study of Fine Coal Recovery And Handleability

Wu-Wey Wen
National Energy Technology Laboratory
U. S. Department of Energy
P. O. Box 10940
Pittsburgh, PA 15236-0940
Phone: 412-386-5713
Fax: 412-386-4810
Email: wen@netl.doe.gov

Richard P. Killmeyer
National Energy Technology Laboratory
U. S. Department of Energy
P. O. Box 10940
Pittsburgh, PA 15236-0940
Phone: 412-386-6409
Fax: 412-386-4810
Email: killmeyer@netl.doe.gov

David J. Akers
CQ Inc.
160 Quality Center Road
Homer City, PA 15748
Phone: 724-479-3503
Fax: 724-479-4181
Email: dakers@cq-inc.com

A continuous bench-scale test of the GranuFlow Process was conducted using a screen-bowl centrifuge for the dewatering and reconstitution of an ultra-fine bituminous coal from Alabama. The objectives of this test were to recover the ultra-fine coal that was lost in the screen effluent, and to enhance the product handleability. In this test, the fine coal slurry was treated with domestic bitumen emulsions that have an appropriate viscosity for fine coal agglomeration. The bitumen emulsions were added into the slurry pipeline, and also into a slurry pre-mixing tank. The test results will be discussed in terms of bitumen dosage, additional coal recovery, moisture reduction, and the handleability.

KEYWORDS

Centrifuge, Dewatering , Emulsion , Dust reduction
Handleability

BACKGROUND

The National Energy Technology Laboratory (NETL) of the U.S. Department of Energy (DOE) had previously developed and patented the GranuFlow Process (Wen and Deurbrouck, 1990; Wen, Gray and Champagne, 1995) which utilizes bitumen emulsions to improve the dewatering of fine clean coal while reducing dustiness and the loss of fines. A coal preparation plant in Alabama processes a very friable bituminous coal that has a Hardgrave grindability index (HGI) of about 90-100. Currently, long-wall mining generates additional fine coal (about 30-35 wt% minus 325 mesh (45 μm)). The plant loses a significant quantity of fine coal in its centrifuge screen effluent during dewatering, and faces dustiness problems during transportation and storage. Improved

moisture reduction is not the plant's priority, but the recovery of more fine coal is. This paper summarizes NETL's efforts with regard to bench-scale testing of the GranuFlow Process in a 6-inch (15.2-cm) Bird screen-bowl centrifuge with flotation concentrate from this coal preparation plant. The objective was to obtain technical information that could be used to better plan and conduct a plant demonstration test in the near future.

EXPERIMENTAL APPROACH

Testing was designed to examine two issues that were key to a successful plant demonstration test.

- 1) What emulsion should be used? DOE generated a great deal of prior test data (Wen and Killmeyer 1996, 1998a and 1998b; Wen, 2000) based on the use of Venezuelan Orimulsion, but it was from a foreign source and its availability and cost were in question. There was a need to get test data on domestic emulsions that might be commercially feasible, affordable, and available (Killmeyer and Wen, 2000). Thus, several emulsions were tested from Asphalt Materials, Inc.
- 2) What effect did the degree of mixing of the emulsion with the coal slurry have on its effectiveness? Plant design can limit how an emulsion might be added to the coal slurry at the proper point to ensure that the asphalt gets intimately mixed with the coal particles. Ideally, it is desirable to just add the emulsion in the slurry stream pipe with sufficient distance and turbulence ahead of the dewatering device to ensure good mixing. During the tests, the mixing was changed by adding the emulsion either to the tank or to the feed line.

Table 1. Types and characteristics of emulsions tested.

Emulsion Type	Surface Charge	Bitumen Formulation	Bitumen Droplet Size	Emulsion Viscosity	Remarks
Heritage-CCB	Cationic	70% o/w	3 microns	25 SFS @ 25 C	Pumpable at room temperature
Heritage-CBH	Cationic	57% o/w	5 microns	30-70 SFS @ 25	Heated for pumping
Heritage-CBM	Cationic	50% o/w	3 -6 microns	30-40 SFS @ 25 C	Tank mixing (unable to pump)

Table 2. GranuFlow testing results (with 6" Bird screen-bowl centrifuge) on the centrifuge feed of Alabama bituminous coal (at 3 gpm feed rate, 17 wt% slurry solids, 12.0 wt% total ash, and 45 wt% solids minus 150 mesh).

Test Date	Emulsion Dosage*, wt%	Product Moisture, wt%	Product Ash, wt%	Main Effluent Solids, wt%	Main Effluent Ash, wt%	Screen Effluent Solids, wt%	Screen Effluent Ash, wt%	Dust Index, %	Dust Reduction Efficiency, %
Test DC2 -Effect of CCB Emulsion (from Ginger Hill tanker emulsion of 4/20/00)									
8/22/00	0	21.7	8.3	1.0	30.7	35.5	20.3	33	27
8/22/00	1	24.0	8.6	0.6	NA	23.1	NA	9	80
8/22/00	3	23.0	8.3	0.3	NA	9.3	NA	3**	93**
8/22/00	5	21.9	8.0	0.3	27.3	5.3	NA	2	96
Test DC3 -Effect of heated CBH emulsion (centrifuge screen was plugged about 70% after test)									
8/22/00	0	21.2	8.3	1.4	21.3	40.4	20.3	27	40
8/22/00	4	24.9	7.6	0.4	15.7	0.8	13.8	2	96
8/22/00	6	23.7	7.8	0.6	13.8	1.5	13.0	2	96
8/22/00	9	22.7	7.6	0.4	14.2	1.5	22.4	2	96
Test DC4 -Effect of CCB Emulsion (from Ginger Hill tanker emulsion of 4/20/00)									
11/14/00	0	14.7	12.5	1.2	37.3	35.2	20.3	28	38
11/14/00	1	16.8	13.1	0.8	30.2	34.5	24.6	6	87
11/14/00	2	18.2	13.0	0.6	28.0	27.9	22.7	5	89
11/14/00	4	19.4	12.9	0.5	27.4	19.7	19.1	1	98
Test DC5 -Effect of CBM Emulsion: (tank mixing was performed at 50% bitumen emulsion)									
11/14/00	0	14.7	12.5	1.2	37.3	35.2	20.3	28	38
11/14/00	1	17.6	10.8	1.0	27.6	22.2	23.6	4	91
11/14/00	2	13.8	12.0	0.6	27.5	11.0	17.3	2	96
11/14/00	4	16.6	10.3	0.6	21.3	1.1	19.1	0	100

* wt% of bitumen per wt. of coal

** Estimated

NA: not available

Table 3. Approximate solids balance for the flotation concentrate of Alabama bituminous coal with selected emulsions.

Test No.	Emulsion Type & Dosage*, wt%	Solids Balance, wt%			
		Feed	Product	Centrifuge Effluent	Screen Effluent
DC2-1	CCB, 0	100	87.4	5.1	7.5
DC2-2	CCB, 1	100	93.0	3.0	4.0
DC2-3	CCB, 3	100	97.2	1.5	1.3
DC2-4	CCB, 5	100	97.6	1.4	1.0
DC3-1	CBH, 0	100	82.9	7.8	9.3
DC3-4	CBH, 4	100	97.7	2.0	0.3
DC3-3	CBH, 6	100	96.8	2.6	0.6
DC3-2	CBH, 9	100	97.8	1.6	0.6
DC4-1	CCB, 0	100	87.0	6.2	6.8
DC4-2	CCB, 1	100	89.7	3.9	6.4
DC4-3	CCB, 2	100	91.1	3.5	5.5
DC4-4	CCB, 4	100	92.8	2.3	4.9
DC5-1	CBM, 0	100	84.9	10.9	4.2
DC5-2	CBM, 1	100	87.6	8.3	4.1
DC5-3	CBM, 2	100	95.3	3.5	1.2
DC5-4	CBM, 4	100	96.1	3.7	0.2

* wt% of bitumen per wt. of coal

The main parameters of interest for determining the successful performance of the process were (1) screen effluent solids reduction, (2) product dust reduction, and (3) product moisture reduction (Wen and Killmeyer 1996). In addition, some information about the performance can be ascertained by looking at the ash contents of the solids in the various streams to see if there is any indication of selective recovery of coal particles.

Coal slurry

The drums of coal slurry used for testing were obtained from the coal preparation plant in Alabama. This was the flotation concentrate material that was fed to the screen bowl centrifuges in the plant. In general, the feed slurry had a solids content between 30 and 34 wt%, with an average ash content of 12.0 wt%. This solids content was too high for the NETL Bird centrifuge to handle properly, therefore, the concentrate was diluted to 17 wt% solids for all of the bench-scale tests. The coal was about 45 wt% finer than 150 mesh (106 μm).

Emulsion type

The emulsions tested were obtained from Asphalt Materials, Inc. in Indianapolis and their characteristics are listed in Table 1. The CCB emulsion, cationic coal binder emulsion, was the same emulsion successfully tested at a GranuFlow demonstration test at the Ginger Hill waste pond coal recovery facility. The CBH emulsion was a modified CCB with a slightly harder bitumen than CCB, while the CBM was also a modified CCB with the hardness of bitumen between that of CCB and CBH. During our tests the CCB emulsion was added into the centrifuge slurry feed line with no centrifuge screen-plugging problem after testing. This is consistent with the Ginger Hill demonstration test. The CBH emulsion could not be pumped into the slurry feed line without a small amount of heating. However, there was some centrifuge screen plugging after testing. It is believed that the bitumen used in CBH is slightly hard for the process. Because the CBM emulsion became unstable when fed with a gear pump, it was added into a slurry-mixing tank and no centrifuge screen plugging was found after testing.

Centrifuge and feed system configurations

The screen bowl centrifuge used was a 6-inch (15.2 cm) x 12-inch (30.5-cm) Bird centrifuge with a 5-inch (12.7-cm) x 3.75-inch (9.5-cm) screen section, 2-inch (5.1-cm) long beach zone, 0.5-inch (1.3-cm) pool depth, 2500 rpm bowl rotation, feed ports 2.75-inch (7-cm) from the beach zone, and a 35 mesh (425 μm) screen. A 50-gallon (190 L) feed tank was used with a Turbon mixer and centrifugal recirculation pump. The coal slurry was fed to the centrifuge using a 6 gpm Moyno screw type pump and a Micromotion mass flow meter. The pump used to inject the emulsions was a 0.1 gpm Viking gear pump that fed into a 0.5-inch (1.3-cm) x 20-feet (6-m) feed line. The injection

point was at the beginning of the feed line, right after the Micromotion, in order to maximize the mixing of the emulsion with the coal slurry. This is an important factor in successfully implementing the GranuFlow Process.

Procedures for analysis of samples

Moisture content -- The moisture contents of the product coal samples from each test were determined by placing the coal in a pan which was placed in a drying oven at 105 degrees C. The pans were removed and weighed several times until no change in the weight was noted.

Dust Index and Dust Reduction Efficiency -- To evaluate the performance of the GranuFlow Process for dust control, NETL adopted a simple Ro-Tap dry screening process to experimentally measure the dust index (I_i) of the cakes. Dust reduction efficiency (E) is calculated based on the following equation.

$$E = \frac{I_0 - I_i}{I_i} \times 100$$

Where,

E = dust reduction efficiency of dry cake, %.

I_0 = dust index of feed coal, cumulative weight percent of feed coal finer than 150 mesh (106 μm) by wet screening.

I_i = dust index of cake, cumulative weight percent of dry cake finer than 150 mesh (106 μm) after Ro-Tapping for 5 minutes.

RESULTS AND DISCUSSION

Test series

Four series of tests and three cationic bitumen emulsions were run in the Bird centrifuge between August and November 2000. The CCB emulsion used was the same one that performed successfully in a GranuFlow demonstration test at the Ginger Hill waste coal recovery facility in April 2000. Table 2 summarizes the test results. These results indicate that treatment with any of the emulsions provided significant decreases in the screen effluent solids and dust index as compared with no treatment.

During the tests, timed samples of product solids, main effluent, and screen effluent were collected. The solids balance for each test is tabulated in Table 3. Note that the average product moisture contents of the untreated product samples were quite different between the August and the November tests, which were around 21 wt% and 15 wt%, respectively. The possible reasons for this difference are 1)

plant sample variation or aging, and 2) a change in the sample analysis personnel.

Emulsion aging problem

Because the above four series tests as shown in Table 2 were performed at two different times, but the CCB emulsion used in tests DC2 and DC4 were from exactly the same source (Ginger Hill tanker in April 2000), the results were quite different. This was particularly evident from the screen effluent solids contents. It was realized after the tests that the stability of the CCB emulsion is best within 60 days of manufacture. Obviously, the effectiveness of CCB in the test performed in November 2000 was not as good as in the test performed in August 2000 due to the aging effect of the emulsion. In order to avoid this aging problem, Asphalt Materials suggests that CCB emulsion should be used within 60 days of production, or that surfactant be added to improve the stability and keep the emulsion droplet size constant.

Mixing method

The normal procedure is to inject the emulsion into the slurry feed line as the centrifuge is operating at a point about 20 feet (6 m) upstream from the centrifuge. The normal feed rate is about 3 gpm. The CCB and CBH emulsions were pumped into the slurry feed line, but tank mixing (emulsion added to the slurry feed tank, not the feed line) was used for CBM because the pumping action broke the emulsion.

The results from the tests on mixing method were similar in product recovery, screen effluent solids reduction, and dust index with the addition of various emulsions; it appears that the different methods were all successful. Each method provided decreases in screen effluent solids and dust index compared to the untreated tests. The tank-mixing test results were somewhat unexpected because it was generally thought that this method did not provide as high a degree of high-shear, intimate mixing as the inline method. Additional research is needed to compare different mixing methods with the same type of emulsion.

Coal product recovery and screen effluent solids reduction

The reduction in screen effluent solids due to the addition of emulsion directly results in an increase in coal product recovery. Figure 1 and Figure 2 show that the centrifuge product recovery increase and the effluent solids reduction were significant with the GranuFlow Process. Looking at the CCB emulsion in Figure 1 for example, the solids distribution to the product is shown to dramatically increase from 87.4 wt% for the untreated slurry to 97.6 wt% for the 5.0 wt% dosage slurry. This is primarily due to the recovery of discarded coal from the screen effluent, which saw its solids content drop from 35.5 wt% in the untreated test to 5.3 wt% in the 5.0% dosage test as seen in Figure 2.

Even a dosage of only 3.0 wt% was enough to provide a significant decrease in screen effluent solids from 35.5 wt% to 9.3 wt%. If the CCB emulsion had not been subjected to a minor aging effect, the screen effluent solids could be even lower, which translates into higher coal production.

Handleability and dust reduction

The handleability of the centrifuge product was greatly improved with the addition of emulsion. Free-flowing granules, as opposed to wet lumpy material, were clearly observed with emulsion additions at or above 1.0 wt%. Figure 3 indicated that the dust index showed a significant decrease upon application of the CCB emulsion, going from 33 % in the untreated test, to 3 % in the 3.0 wt% dosage test. With CBM and CBH emulsions, a dosage of 1.0 wt% and 4.0 wt% could accomplish a significant decrease in the dust index from 28 % to 2 % and from 27 % to 2 %, respectively.

Moisture reduction

In these test series as shown in Table 2, there was no additional moisture reduction evident in the centrifuge product with CCB, CBH and CBM emulsions. The untreated product moisture with CCB emulsion was 21.7 wt%, while the treated products ranged between 21.9 and 24.0 wt%. This was somewhat of a departure from previous testing, as documented in earlier papers, in which there was often a few percentage points reduction in the product moisture when applying the GranuFlow Process. This may have been due to the characteristics of the particular coal slurry being treated. On the other hand, there is also evidence that the product moisture does not change, or may even increase, due to the quantity of additional high-moisture fines that are recovered from the effluent streams as a result of the process.

CONCLUSIONS

- 1) The addition of a bitumen emulsion via the GranuFlow Process did significantly increase the amount of solids recovered in the product stream from the screen-bowl centrifuge. This is primarily due to the dramatic reduction of material being lost in the screen effluent stream. The fine coal particles become agglomerated with the bitumen and are less likely to be lost through the centrifuge screen section.
- 2) The addition of a bitumen emulsion significantly decreased the dust index due to the agglomeration of the fine particles, and turned the wet sticky fines into a granular, free-flowing, dust-free product. This greatly improves the product handleability.
- 3) Based on the results from the tests that were run, treating the coal concentrates with bitumen emulsion did not appear to produce consistent moisture results. Historically, the GranuFlow Process provides some improvement in product moisture. However, in these

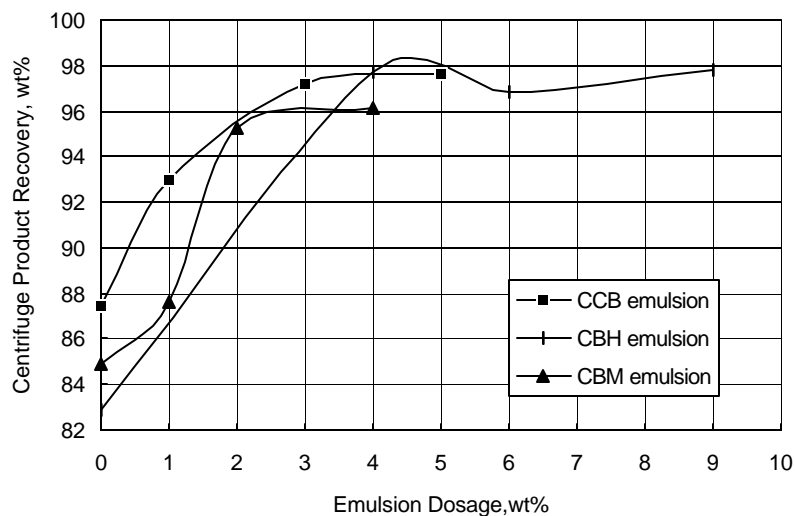


Figure 1. Centrifuge product recovery with the application of the GranuFlow Process on the flotation concentrate of Alabama bituminous coal with various emulsions.

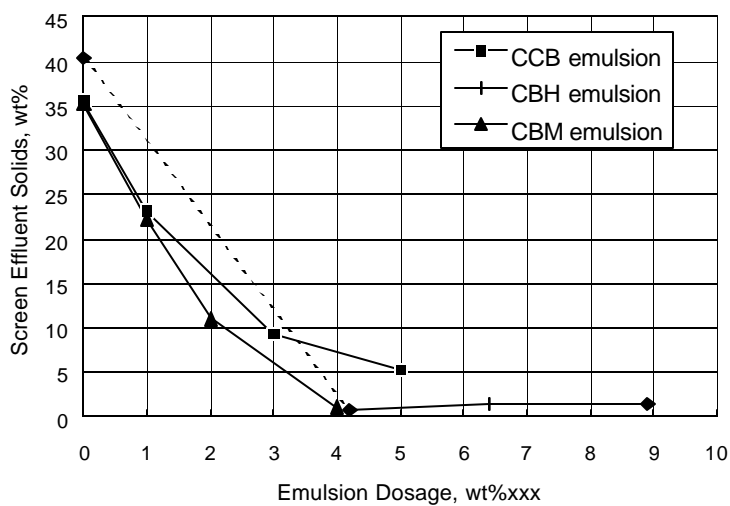


Figure 2. Screen effluent solids reduction with the application of the GranuFlow Process on the flotation concentrate of Alabama bituminous coal with various emulsions.

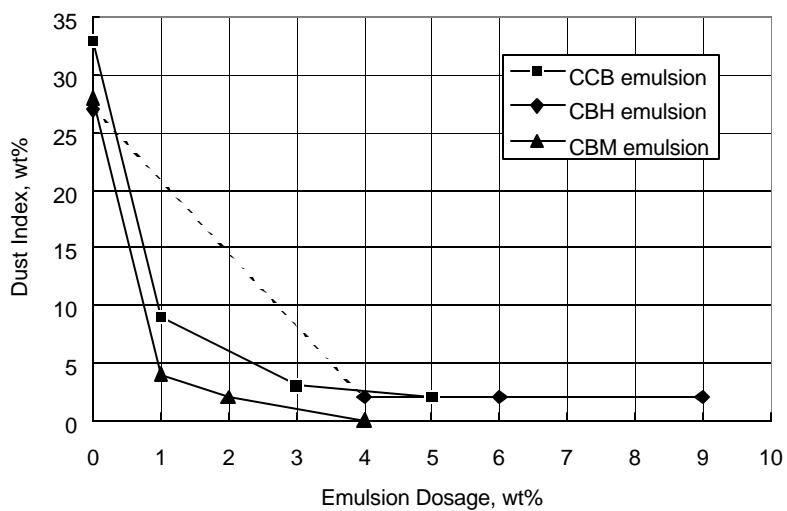


Figure 3. Dust index on the application of GranuFlow Process on the flotation concentrates of Alabama bituminous coal with various emulsions.

tests, the moisture content of the treated coal product varied not only between emulsions but also among the different dosages of the same emulsion. In some cases, emulsion treatment showed a slight increase, in others there was a negligible effect, and in others there was a small decrease. Overall, a slight increase in moisture content was noted with most emulsion treatments, probably due to the additional recovery of high-moisture fines from the screen effluent as a result of the process.

- 4) In addition, particularly in the case of CBH emulsion, there appeared to be selective recovery of coal as opposed to mineral matter, as indicated by lower ash contents in the product solids, or higher ash contents in the effluent solids.
- 5) All of the various bitumen emulsions tested all seemed to perform in a manner similar to that of Orimulsion. This means that in the pursuit of an emulsion for commercial applications, efforts can concentrate on finding candidates that are available and economical with some assurance that they will also be technically feasible. One issue that does need to be considered in evaluating an emulsion is how the “stickiness” of the bitumen affects the centrifuge with regard to screen blinding.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Mr. Robert Elstrodt, Mr. John Kleinhenz, and Mr. Adrian Woods of NETL for their technical contributions and efforts; and Mr. Paul Zandhuis of Parsons Power for his technical assistance.

DISCLAIMER

Reference to any specific commercial product, process, or service are for understanding only and do not imply

endorsement or favouring by the United States Department of Energy.

REFERENCES

Wen, W.W., and Deurbrouck, A.W., 1990. Combined method for simultaneously dewatering and reconstituting finely divided carbonaceous material. U.S. Patent No. 4,969,928.

Wen, W.W., Gray, M.L., and Champagne, K.J., 1995. Method for simultaneous use of a single additive for coal flotation, dewatering, and reconstitution, U.S. Patent No. 5,379,902.

Wen, W.W., and Killmeyer, R.P., “Centrifugal dewatering and reconstitution of fine coal: the GranuFlow Process”. *Coal Preparation*, Vol. 17, 1996, pp. 89-102.

Wen, W.W., Killmeyer, R.P., “The application of the GranuFlow Process to centrifuge dewatering at the Terry Eagle Plant”. *15th Int. Coal Prep. Exhibition & Conference*, 1998a.

Wen, W.W., Killmeyer, R.P., Field testing and commercialization of the U.S. Department of Energy’s GranuFlow process. XIII International Coal Preparation Congress., Brisbane, Australia, 1998b.

Wen, W. W., “An integrated coal preparation technology: the GranuFlow Process”. *Int. J. Mineral Proces*, Vol. 58, 2000, pp. 253-265.

Killmeyer, R.P., and Wen, W.W., “Topical report on bench-scale testing of the GranuFlow process for planning the Ginger Hill demo test”. *DOE/NETL CRADA report*, 2000